Alternative Fuels and Systems for Refuse Trucks

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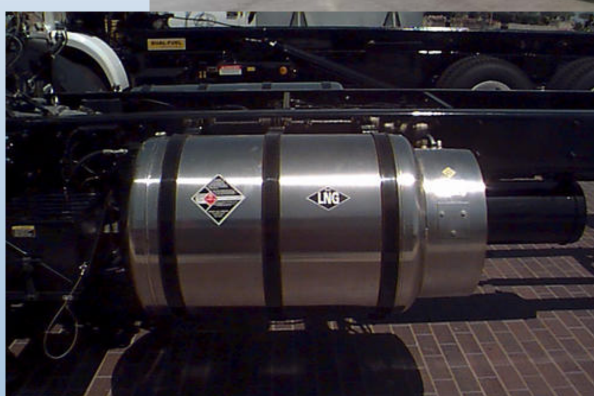
Outline

Purpose: Overview of alternative fuel and advanced propulsion technologies for refuse applications, which reduce regulated emissions and potentially lower O&M costs

- Alternative fuels
  - Natural gas
    - Natural gas engine and vehicle R&D
    - Landfill gas to LNG
  - Biodiesel blends
- Hybrid propulsion systems
  - Hydraulic hybrids
  - Hybrid electrics

Natural Gas



New Jersey EcoComplex, Burlington Co., NJ

Natural Gas Engines

- Benefits
  - Petroleum displacement
  - Meet EPA emissions requirements ahead of schedule
  - Less noise than conventional diesel
  - No diesel smell
  - Lower fuel cost
    - NG – Roughly $1.50/diesel gallon equivalent
    - Diesel – Over $2/gallon
  - O&M costs are becoming equivalent to diesel
  - Carl Moyer credits
- Issues
  - Fueling station cost
  - Limited range with CNG; less of an issue with LNG

Next Generation Natural Gas Vehicle Activity

- DOE, NREL, SCAQMD, CEC started Next Generation Natural Gas Vehicle activity in 2000
  - Focused on developing natural gas engines and platforms for medium- and heavy-duty applications
  - Meet or beat EPA standards
    - 2007 - 1.2g/bhp-hr NOx; 0.01g/bhp-hr PM
    - 2010 - 0.2g/bhp-hr NOx; 0.01g/bhp-hr PM
  - Conducted workshops involving engine and vehicle OEMs and other stakeholders to gather their input

Next Generation Natural Gas Vehicle Activity

- Market assessment indicated refuse trucks and transit buses best applications of NG engines
- Vocation profile data included
  - Annual mileage
  - Range
  - Power requirement
  - Fuel economy
  - Refueling practices
  - Trade cycles
- End users surveyed to assess decision factors
  - Reliability
  - Maintenance cost
  - Vehicle purchase cost
- Lifecycle cost analysis indicated vehicle cost and annual mileage/fuel use are most critical to refuse collection
- Less critical – fuel cost, fuel station cost, annual maintenance cost

Natural Gas Engine Development

- Current or near-term availability
  - Cummins Westport (1.5g NOx + NMHC)
    - B Gas Plus; 5.9L; 195 hp; 420–500 lb-ft torque
    - C Gas Plus; 8.3L; 250–280 hp; 660–850 lb-ft torque
    - L Gas Plus; 8.9L; 320 hp; 1000 lb-ft torque
  - John Deere (1.2g NOx)
    - 6081H; 8.1L; 250–280 hp; 735–900 lb-ft torque
  - Mack (aiming for 2010 EPA compliance)
    - E7G; 12L; 325hp; 1250 lb-ft torque
  - Clean Air Power (2007-2010 EPA compliance)
    - C-13 Caterpillar; 13L; 425hp; 1450 lb-ft torque
- 2010 EPA compliant engines are being developed for MY2007 production

Natural Gas Engines

- NREL has performed in-service evaluations of natural gas refuse trucks
  - Waste Management; Washington, PA
  - Norcal Waste System; San Francisco, CA
  - Los Angeles Bureau of Sanitation
- Evaluations available on Advanced Vehicle Testing website
  - http://www.avt.nrel.gov/trucks.html
- Results
  - Start-up problems were experienced but were overcome
  - Drivers reported that the performance of the natural gas trucks was as good or better than diesel
  - Fuel economy for natural gas engines is improving
  - Maintenance costs are higher, but should improve
  - LNG cost was a major component of operational costs

Landfill Gas to LNG

- DOE/Brookhaven National Lab working on LFG to LNG process
- Benefits
  - Greenhouse gas reduction
  - Co-production of food-grade liquid CO_2
  - Imported petroleum displacement
- Sites
  - Arden Landfill in Washington, PA
    - Waste Management; Applied LNG Technology; Mack Truck
  - Burlington County Landfill, NJ
    - Acrion; Mack Truck; Air Products
- Enabling technologies
  - Gas cleanup
  - Liquefiers for LNG (-259ºF)

Landfill Gas to LNG

- Gas cleanup
  - Typical LFG composition: 50% methane, 40% carbon dioxide, and 10% nitrogen, oxygen, volatile organic compounds
  - Challenge is removal of CO_2
  - Acrion CO_2 wash technology looks promising
- Liquefiers
  - Small-scale liquefiers (10,000 gal/day) typically operate at lower efficiency, but adequate using low cost/no cost fuel
  - Design requirements
    - Low initial cost
    - Reliable performance
    - Robust refrigeration system
    - Residual CO_2 removal

Landfill Gas to LNG

- Process energy efficiency roughly 80%
- 1MMBtu methane = 2,000 SCF of LFG = ~10 gal LNG
- System cost effectiveness a function of equipment investment expense, operational cost, available gas volume, and LNG price
- 10K gallon/day process ~ $4M initial cost

Biodiesel

Harvesting rapeseed, a biodiesel feedstock

Biodiesel Blends

- Most diesel engine manufacturers approve B5 (5% biodiesel) blends
- B20 blend is becoming socially acceptable, but not fully supported by engine manufacturers

Biodiesel Blends

- Benefits
  - Petroleum displacement
  - Greenhouse gas emission reduction
  - Increased lubricity
  - No engine or infrastructure modifications required
  - Less PM emissions, diesel odor and smoke (B20)
  - Domestic, “homegrown” fuel
- Issues
  - Slightly higher NOx emissions
  - Fuel quality has been inconsistent
  - Higher cost (may be offset by a tax credit)

Heavy Hybrids

Hydraulic Hybrids

- Pressurized hydraulic fluid captures braking energy
- Reversible hydraulic pump/motor coupled to the driveshaft
  - Braking pumps fluid from low pressure to high pressure accumulator
  - During acceleration, high pressure fluid flows through hydraulic motor to low pressure accumulator to provide torque to the driveshaft
- Peterbilt and Eaton are developing a Model 320 using Hydraulic Launch Assist™

Hydraulic Hybrids

- Benefits
  - Higher fuel economy
  - Reduced vehicle emissions
  - Reduced brake and drivetrain wear
  - Equal or improved vehicle acceleration
  - Lower cost than electric hybrids
- Issues
  - Unproven technology

Hybrid Electric Vehicles

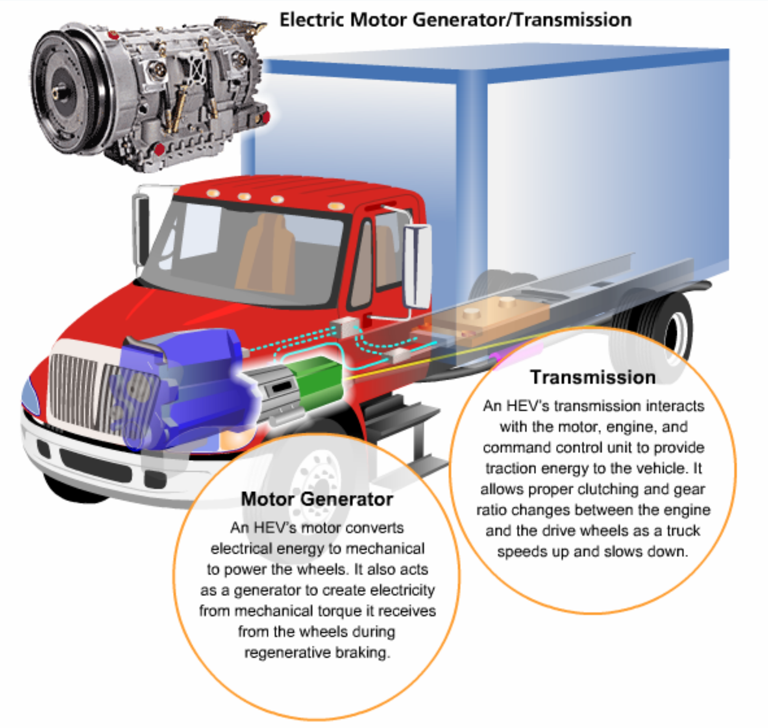
- Hybrid electric systems manipulate electrical energy
  - Generator operates during coasting, braking, idling
  - Energy stored in batteries and/or ultracapacitors for use by electric motor during acceleration
  - Electric motor and ICE can operate together (parallel) or ICE can function as a generator (series)
- Benefits
  - Improved fuel efficiency
  - Reduced emissions
  - Lower operational costs due to decreased brake wear
  - Improved acceleration
- Issues
  - High cost
  - O&M costs could be high

DOE Advanced Heavy Hybrid Propulsion Systems (AH^{2}PS) Project

- AH^{2}PS goal is to commercialize vehicles by 2010
  - Increase powertrain efficiency 100%
  - Meet 2007-2010 EPA emissions standards
  - Increase component reliability and durability
- Project teams
  - Eaton/International/Ricardo
  - Oshkosh/Rockwell/Ohio State U.
  - General Motors/Allison transmission
  - Caterpillar Inc.

Advanced Heavy Hybrid Propulsion Systems Project

- Next-generation technologies
  - Propulsion systems
  - Engine technologies
  - Motor/generator technologies and motor control
  - Energy storage architectures/systems
  - Power electronics & control systems
  - Auxiliary load electrification
  - Advanced vehicle systems modeling & optimization
  - Waste heat recovery systems
  - Heavy hybrid testing development
- Hybrid electric transit buses are starting to emerge; no commercial product on the horizon for trash haulers



Summary

- Emerging alternative technologies reduce regulated emissions and are targeted to provide lower O&M costs
- Some technologies are ready-to-go
  - Natural gas
  - Biodiesel
- Others are near term
  - Landfill gas
  - Hydraulic hybrid
- Longer term
  - Hybrid electrics
  - Fuel cell